Broadband Radiation and Scattering

For more information contact **Robert M. Sharpe**
(925) 422-0581, sharpe1@llnl.gov

We will enhance our computational electromagnetics (CEM) capability in the area of broadband radiation and scattering. Broadband analyses include electromagnetic interference and electromagnetic compatibility noise analysis, broadband radar, and accelerator wakefield calculations. LLNL analysis codes are limited by the accuracy of radiation boundary conditions (RBCs), which truncate space. We will develop improved RBCs by extending the perfectly matched layer (PML) approach to non-Cartesian meshes, and by developing discrete-time-domain, boundary-integral techniques, which are compatible with high-accuracy, finite-element methods and capable of arbitrary accuracy. We will compare the two approaches for accuracy and efficiency for a variety of radiation and scattering problems.

Project Goals

The ultimate deliverable is an enhanced CEM capability that can provide accurate and efficient computational solutions to broadband radiation and scattering problems. The algorithms for improved RBCs will be incorporated into LLNL's existing EMSolve code. The result will be a 10- to 1000-fold improvement in the accuracy of simulations. Improved algorithms and our existing high-performance computer hardware will place LLNL's CEM activity among the top capabilities in the world.

This research and the resulting capability will be documented in appropriate peer-reviewed publications.
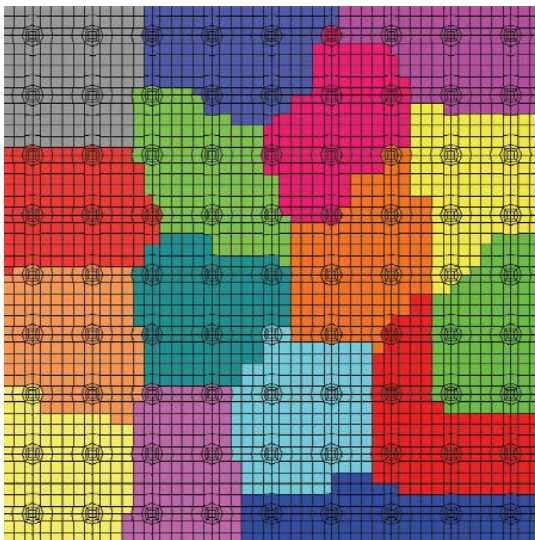
Figure 1. Computational mesh for a parallel simulation of a photonic bandgap structure. The colors denote the parallel partitioning. This is an unstructured hexahedral mesh using higher-order curved elements for the dielectric rods.
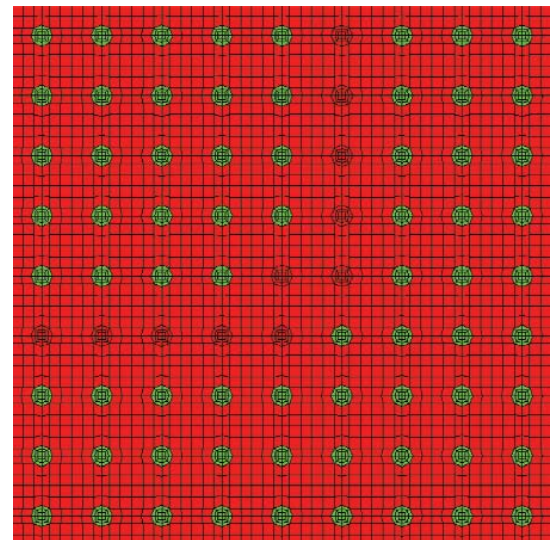
Figure 2. Computational mesh for a photonic bandgap simulation. The structure is an artificial crystal consisting of dielectric rods (green) in a bulk dielectric (red). The structure is designed to prohibit light waves of a prescribed wavelength. A photonic waveguide is constructed by removing rods. In this example the waveguide makes a 90° bend.

Relevance to LLNL Mission

Electromagnetics is a truly ubiquitous discipline that touches virtually every major LLNL program. Our work supports the national security mission by reducing the time and money spent in building and testing existing programs. It will enable computer simulations for new devices and systems, performance analysis of systems critical to nonproliferation efforts, and the design of micropower impulse radar and other microwave systems.

## FY2004 Accomplishments and Results

Figures 1 to 4 are sample results for our CEM work.

We extended the PML concept to higher-order unstructured grids and analyzed the performance of this approach. We performed novel higher-order photonics simulations that would not have been possible without these extensions to the PML concept. Results were presented at a 2004 IEEE conference, and a manuscript has been submitted to *The Journal of Computational Physics*. On the boundary integral task, we developed a prototype code used to evaluate various boundary integral formulations. Significant effort

was spent on investigation of numerical instabilities. We determined that temporal basis functions (as opposed to temporal differencing) are required for stability.

FY2005 Proposed Work

The stability and accuracy of the boundary integral approach depends critically on the integration, or quadrature rules. We will continue to research singularity extraction, polar integration, and Duffy transformation-based quadratures. We are collaborating with a professor at the University of Washington, an expert on time-domain integral equations, and will collaborate closely with him also on time integration methods and the hybrid finite-element boundary element formulation. We expect to have a fully functioning, although not fully optimized, time-domain boundary integral code working by the end of FY2005. This will enable the full hybridization with finite elements in FY2006.
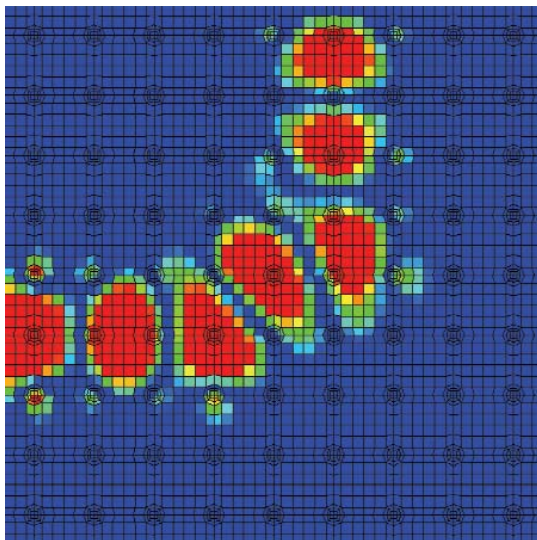
Figure 3. Snapshot of the computed electric field intensity. Note how the light makes a 90° bend, which is not possible with conventional dielectric waveguide technology. This simulation used third-order finite-element basis functions to eliminate numerical dispersion effects. The mesh was terminated with a single-layer third-order PML to absorb the outgoing waves.
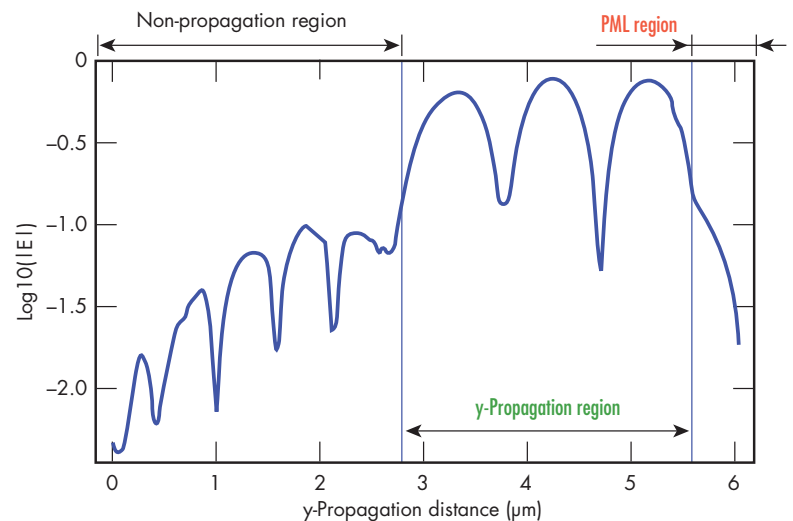
Figure 4. "Line-out" plot of the electric field intensity. This plot clearly shows the outgoing wave being absorbed by the third-order PML region.